# Physical, Biological, and Biogeochemical Response of a Northeastern River to a Severe Flood

**Problem**

A highly unusual situation allows us to assess the effects of channel dewatering, channel creation, and increased sediment loads on the habitat, biota, and ecosystem processes of a large stream. The fourth-order Suncook River in southeastern New Hampshire drains a watershed of approximately 575 $km^2$ and has an average annual discharge of approximately 9 $m^3$ $s^{-1}$. The May 15, 2006 avulsion of the Suncook River naturally created a new stream reach of approximately 800 m (Figure 1). This new reach flows through a wetland and boggy area along the edge of an old railroad bed before converging on an access road, flowing into a sand pit, and rejoining the east branch of the Suncook River. Erosion of unstable sediments in the newly created Suncook River channel contribute to elevated sediment loads in and downstream of this new channel. Creation of the new stream reach resulted in nearly complete dewatering of the abandoned channel to the west (1.25 km long), which is now only fed from Mason Brook, a small tributary (Figure 1).

An examination of the effects of persistent dewatering on the biota and on ecosystem processes is particularly important in New England, which has only recently recognized the importance of instream flow issues. In New Hampshire, a pilot program was recently established for instream flow protection on the Lamprey and Souhegan Rivers, two of the state's fourteen designated rivers. Water quality is intrinsically tied to water quantity; dissolved nutrients and pollutants can be concentrated or diluted depending on instream flow. Stream temperature is regulated, in part, by instream flow, and water quantity determines the extent of instream habitat. The direct and indirect impacts of drought can greatly reduce population densities, species richness and alter life-history schedules, species composition, patterns of abundance, type and strength of biotic interactions (predation and competition), food resources, trophic structure and ecosystem processes (Lake, 2003). Recreational activities such as fishing and boating can also be impacted by significant reductions in stream flow.

Documentation of the effects of continuously elevated sediment loads is also increasingly important in New England and nationally, due to relentless increases in construction activities and the creation of impervious surfaces. Sedimentation of streams affects organisms in two major ways: through physical and chemical changes to the water, and through blanketing of the stream bottom. Specific effects of siltation on aquatic systems include screening out light, changing heat radiation, smothering the stream bottom, and retaining organic material and other substances, which create unfavorable conditions at the bottom (Ellis, 1936). By reducing the stream bottom's permeability to water movement, an increased amount of fine sediments in the streambed can affect the delivery and removal of gases, nutrients and metabolites, and potentially movement of animals (Allan, 1995).

Primary succession, involving site-specific, temporal change occurring after a disturbance that is so intense that no trace of the previous community remains (Fisher, 1990), has rarely been documented in streams at the spatial scale of whole river segments (Milner, 1994). With the proliferation of stream restoration activities that attempt to recreate natural channels (e.g. bypass channels and restored meanders), an understanding of the course and speed of the establishment of structure and function in a new stream would be timely. By advancing knowledge of the way that stream ecology and biogeochemistry respond to large-scale disturbances, this research has practical applications for stream conservation and restoration practices in New England.

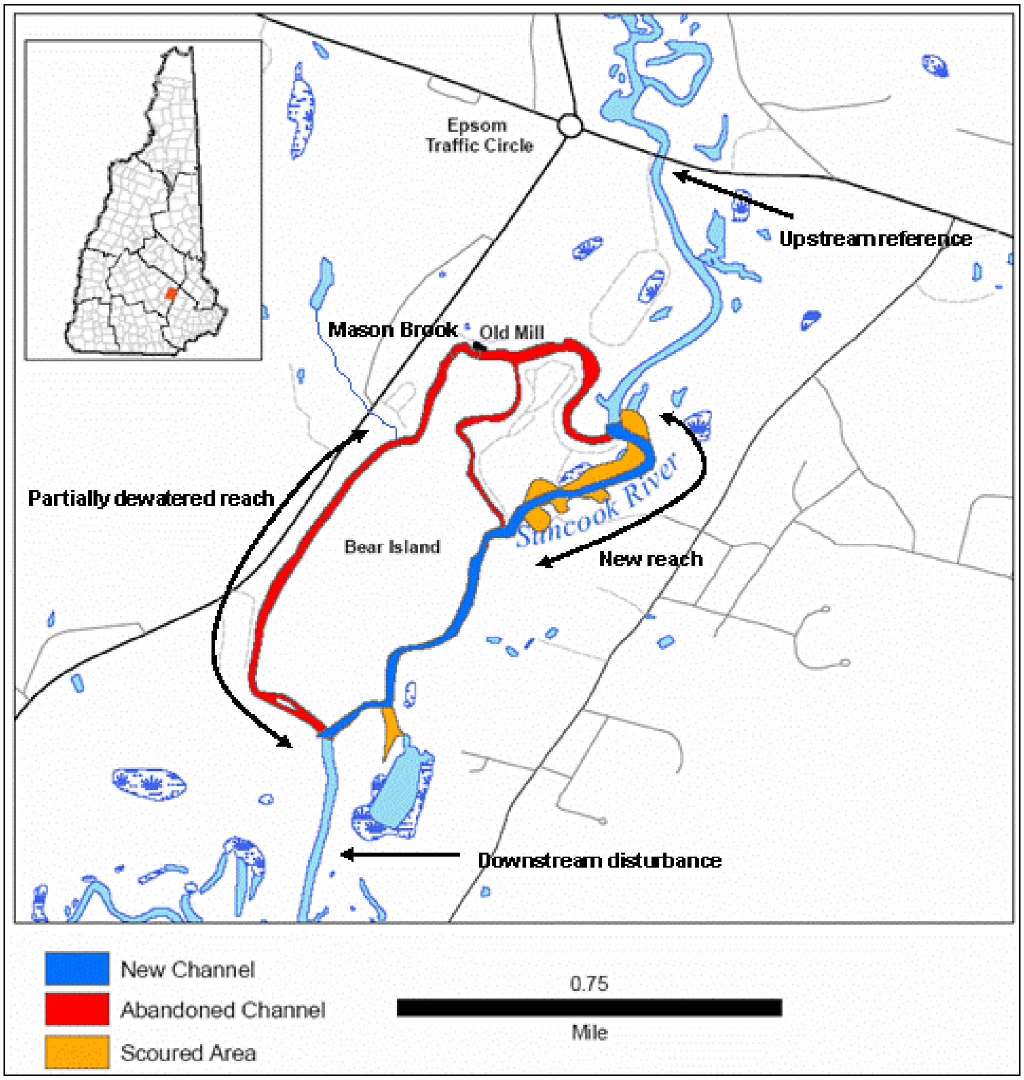


**Figure 1. Changes to the Suncook River in Epsom, NH (Mapping by New Hampshire Geological Survey, NHDES)**

## Objectives

This research seeks to 1) determine the course of habitat transformation; 2) identify changes in biotic communities and; 3) investigate changes in biogeochemical processing in the radically altered Suncook River system. We collected data from three impacted reaches (new channel, dewatered channel, and sediment laden channel downstream of the avulsion) as well as an upstream reference site. We documented changes in: (1) streambed composition, (2) water physiochemistry (including temperature, pH, conductivity, dissolved oxygen, turbidity, suspended solids, DOC, $NH_4^+$, $NO_3^-$, $Na^+$, $K^+$, $Ca^{2+}$, $Mg^{2+}$, $Cl^-$, $SO_4^{2-}$), (3) stream biota (benthic macroinvertebrates, and fish), and (4) ecosystem processes (stream metabolism) of the affected reaches and upstream reference sites. Work was carried out as shown in Table 1, below.

**Table 1. Work plan**

| Activity | Frequency |
|---|---|
| ***Habitat*** | |
| Wolman pebble count | Annually (10/06, 8/07) |
| Water quality parameters (temperature, pH, conductivity, and dissolved oxygen) | Biweekly |
| | |
| ***Ecology*** | |
| Benthic macroinvertebrate collection | Quarterly (7/06, 9/06, 2/07, 5/07, 8/07) |
| Fish survey | Once (8/07) |
| | |
| ***Biogeochemical processing*** | |
| Water samples for nutrient, DOC and cation/anion analysis | Biweekly |
| Stream metabolism | Once (10/07) |

## Methods

Samples were collected at intervals described in Table 1 above. Stratified Wolman (1954) pebble counts (Kondolf, 1997) were carried out to characterize coarse surface substrate. Intermediate axes were measured using a ruler and hand-held gravel analyzer (Gravelometer, US SAH-97, Wildlife Supply Company, Buffalo, NY) for at least 100 particles. Benthic macroinvertebrates were collected using a kicknet sampler and by scrubbing all rocks and disturbing sediment within 1 ft of the kicknet frame. Specimens were preserved in 70% ethanol and subsampled according to EPA's Rapid Bioassessment Protocol for benthic macroinvertebrate collection. Specimens were identified to the family level. Fish were surveyed using electrofishing with backpack electroshockers in collaboration with the New Hampshire Department of Fish and Game. Whole-stream metabolism was measured using the diurnal upstream-downstream dissolved oxygen change technique (Marzolf et al., 1994).

Stream water samples were filtered in the field using pre-combusted glass fiber filters (0.7 µM pore size), and frozen until analysis. All samples were analyzed in the Water Quality Analysis Lab of the WRRC on the campus of UNH, Durham, NH.

The Water Quality Analysis Laboratory (WQAL) was established by the Department of Natural Resources in 1996 to meet the needs of various research and teaching projects both on and off the UNH campus. It is currently administered by the NH Water Resources Research Center and housed in James Hall. Dr. William McDowell is the Laboratory Director, and Jeffrey Merriam is the Laboratory Manager. Together, they have over 35 years of experience in water quality analysis, and have numerous publications in the fields of water quality, biogeochemistry, and aquatic ecology.

Methods for analyses include ion chromatography ($NO_3^-$, $Na^+$, $K^+$, $Ca^{2+}$, $Mg^{2+}$, $Cl^-$, $SO_4^{2}$), discrete colorimetric analysis ($NH_4$, $PO_4$, $NO_3/NO_2$), and high temperature oxidation (DOC, TDN). All methods are widely accepted techniques for analysis of each analyte.

## Major findings and significance

*Geomorphology*

In the eastern branch of the Suncook River, substrate size now steadily decreases from cobbles upstream of the avulsion, to gravel in the new channel, to sand in heavily sedimented downstream portions of the river. Data collected more than one year after the avulsion suggests that this is a long-lasting trend; stream bed substrate within and downstream of the new channel remains small and unstable (Figure 2). This trend appears to have had a major impact on the stream biota and ecosystem processes, as will be described below.

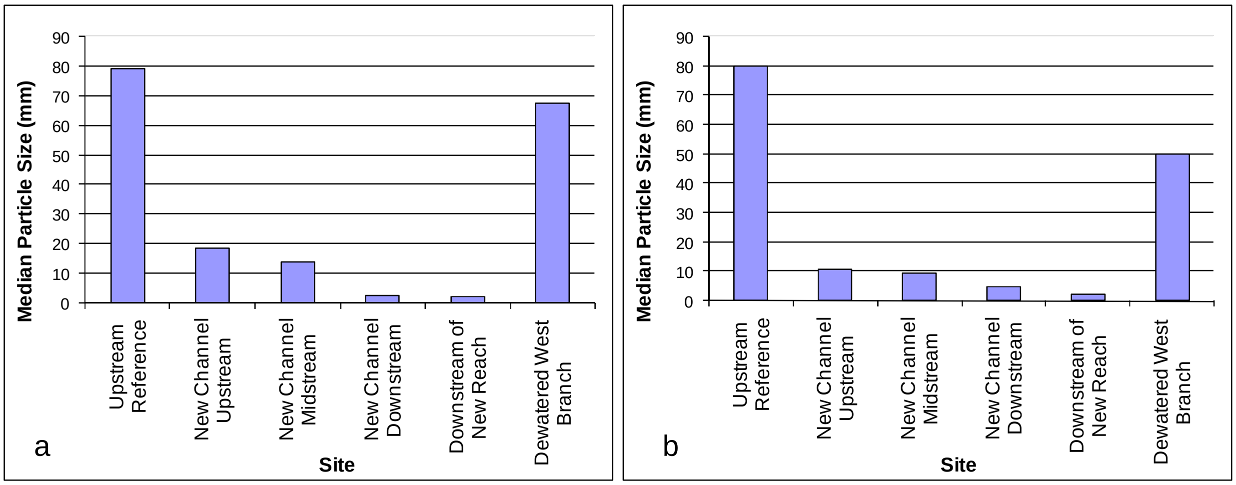


**Figure 2. Substrate size in the Suncook River during (a) October, 2006; and (b) August, 2007.**

*Chemistry*

The avulsion did not lead to noticeable changes in water chemistry in the main channel of the Suncook River. However, dewatering of the west branch of the Suncook River did lead to long-term increases in the concentration of major ions and nitrate in this reach. The concentration of nitrate and chloride over the monitoring period is shown in Figure 3 below; other major ions followed similar trends. The increase in concentration of major ions in the east branch of the Suncook River appears to be due to lesser dilution of high conductivity inputs from Mason Brook. Elevated nitrate concentrations in this reach are much higher than those in Mason Brook and are likely due to agricultural fertilizer inputs nearby in the watershed.

In the new and downstream reaches of the Suncook River where stream bottom substrate is small and unstable, there are also consistently higher concentrations of suspended solids in the water column. Extraordinarily high levels of suspended sediment in the new and downstream reaches of the Suncook River were measured immediately following the avulsion. Over the summer of 2006, these concentrations declined and approached baseline levels. However, notably higher concentrations of suspended solids continue to be found in these reaches during periods of storm flow (Figure 4).

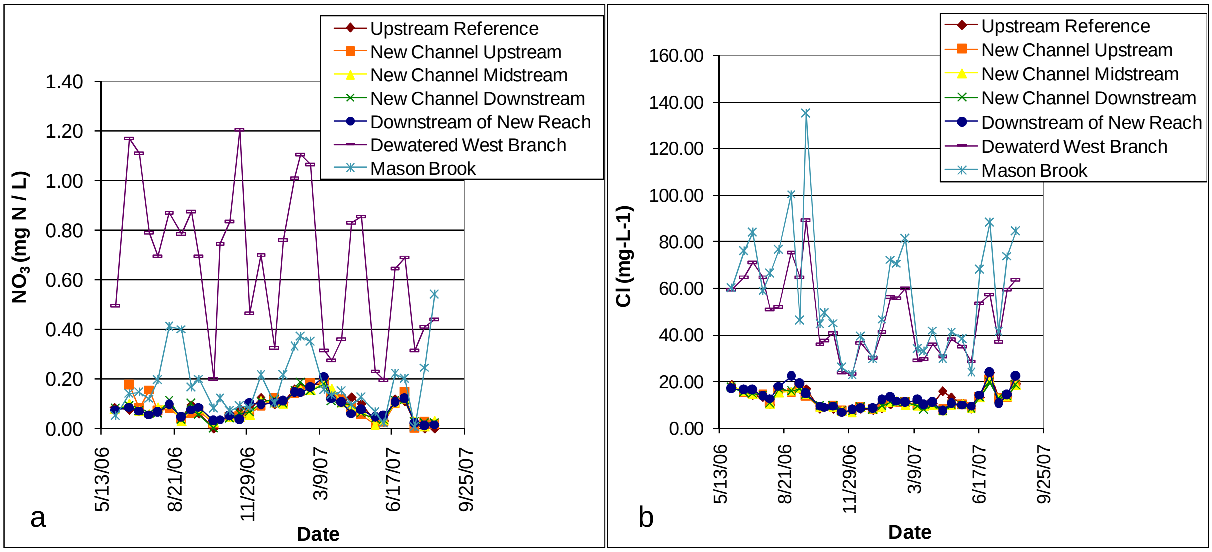

**Figure 3. (a) Nitrate concentration; and (b) chloride concentration in the Suncook River.**

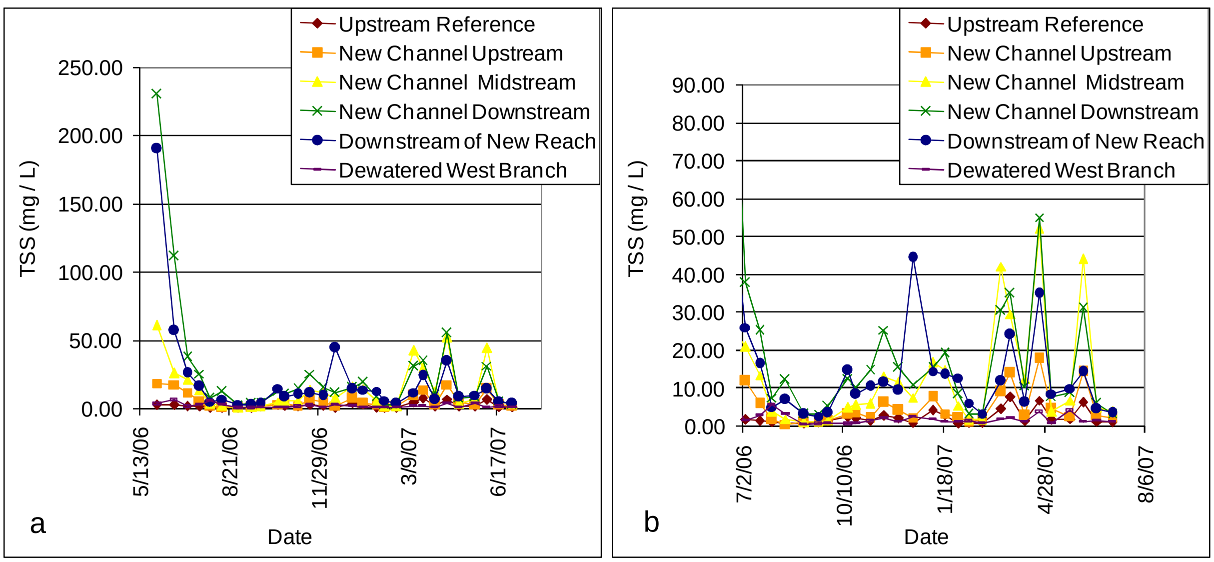

**Figure 4. Suspended solids in the Suncook River (a) 5/06-7/07; and (b) 7/06-7/07 (note altered scale)**

*Biota*

Along with decreasing substrate size and stability and increasing suspended solids as one travels downstream in the eastern branch of the Suncook River, benthic macroinvertebrate abundance declines (Figure 5). Fifteen months after the avulsion, macroinvertebrate density at the reference site is still two orders of magnitude greater than that found in reaches most impacted by sedimentation. Macroinvertebrate abundance in the dewatered channel remains comparable to that found within the reference site.

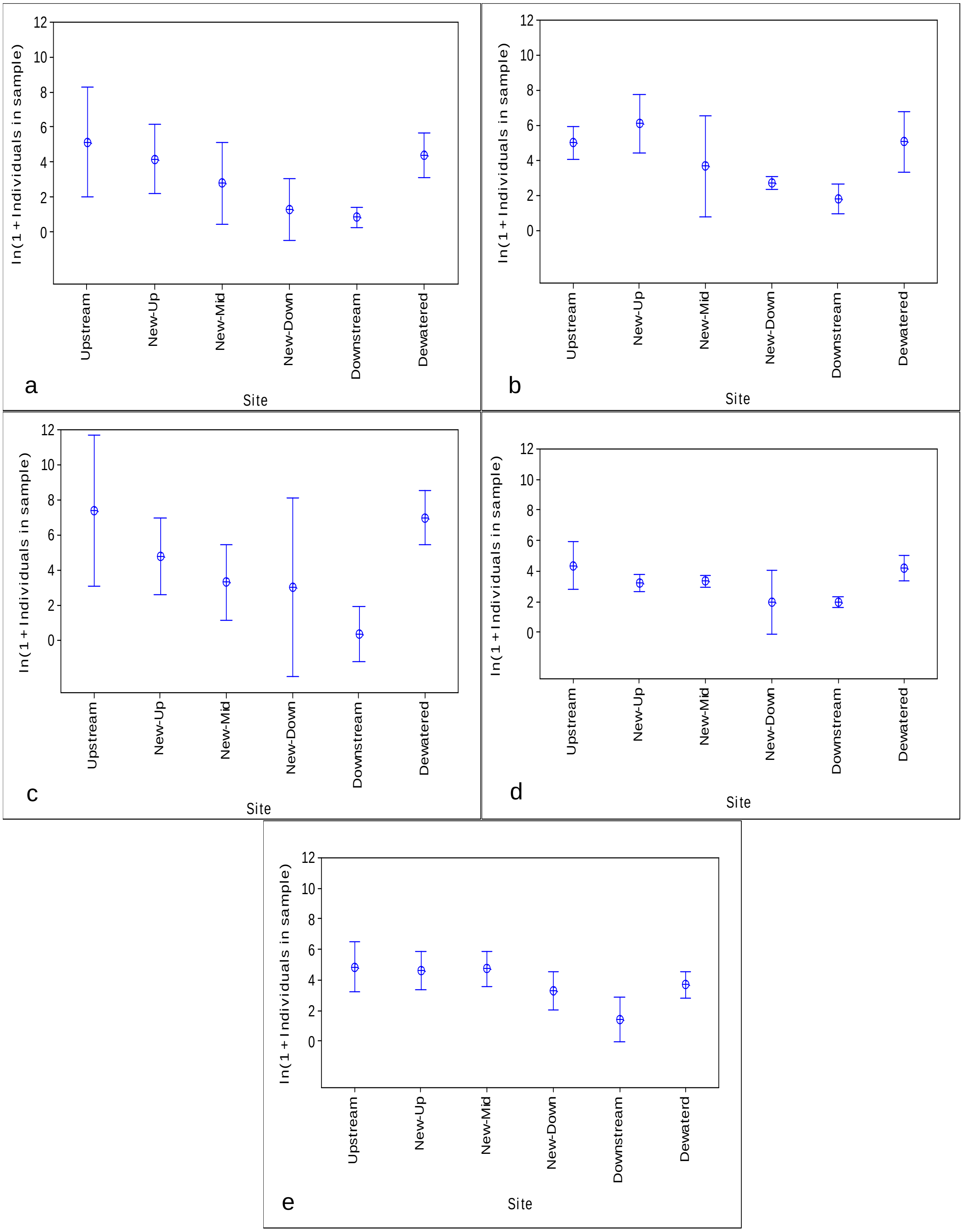

**Figure 5. Macroinvertebrate abundance in the Suncook River (a) 7/06; (b) 9/06; (c) 2/07; (d) 5/07; and (e) 8/07; error bars show standard deviation.**

Fish were surveyed fifteen months after the avulsion at four sites in the Suncook River system. While strong trends in fish community composition in the eastern branch of the Suncook

River were not apparent, the fish community within the dewatered western branch of the Suncook River was dominated by two species: Margined Madtom (*Noturus insignis*) and Fallfish (*Semotilus corporalis*) (Figure 6). Species richness was equal at the upstream reference site, within the new channel, and downstream of the avulsion, with eight different species found at each location. Compared with the reference site, catch per unit effort was slightly lesser in and downstream of the new channel, and much higher in the dewatered west branch (Figure 7).

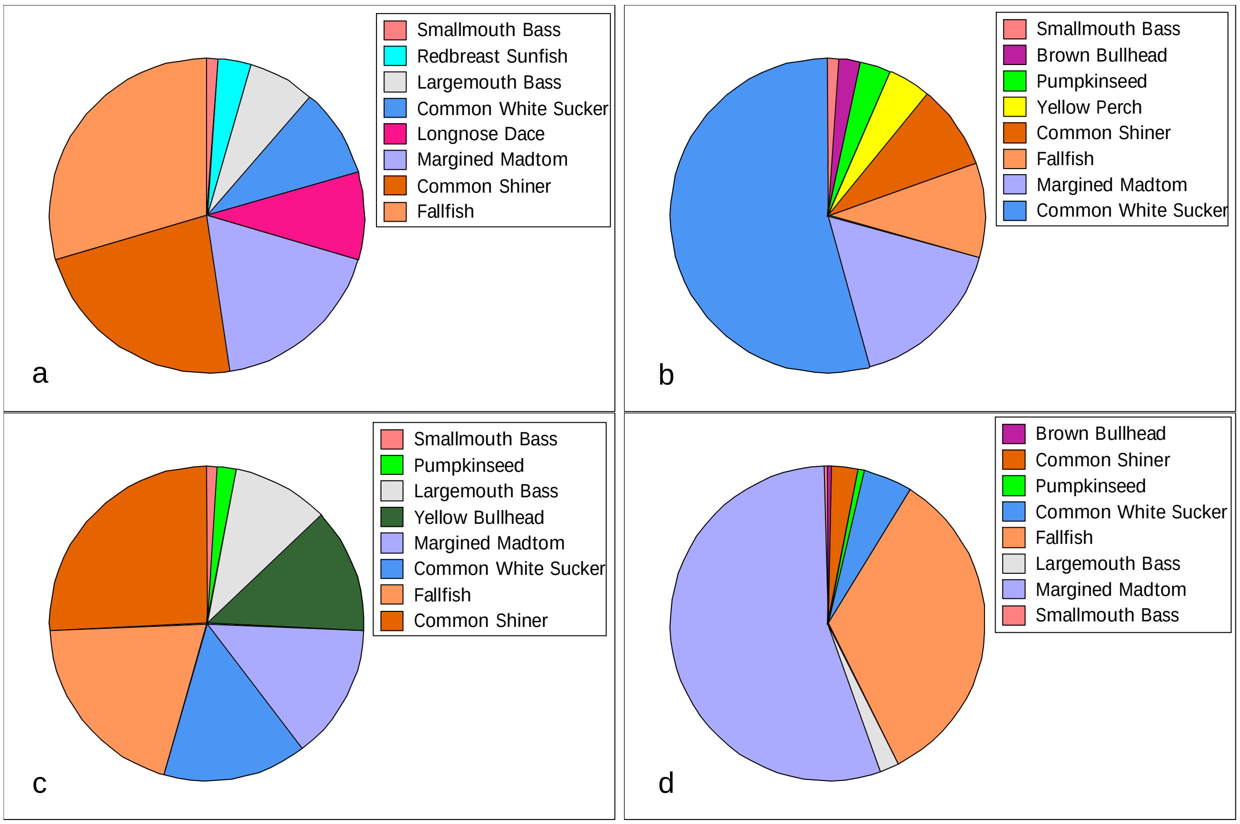


**Figure 5. Fish communities in the Suncook River at (a) upstream reference; (b) new channel; (c) downstream of new channel; and (d) dewatered west branch.**

*Ecosystem Processes*

Whole-stream metabolism in the Suncook River system was measured in October, 2007. At this time, seventeen months after the avulsion, gross primary production and community respiration were markedly depressed in and downstream of the new channel as compared with the reference site (Figures 7a and 7b). Whole stream metabolism in the dewatered west branch was also depressed relative to the reference site when assessed during a subsequent period in October, 2007 (Figures 7c and 7d).

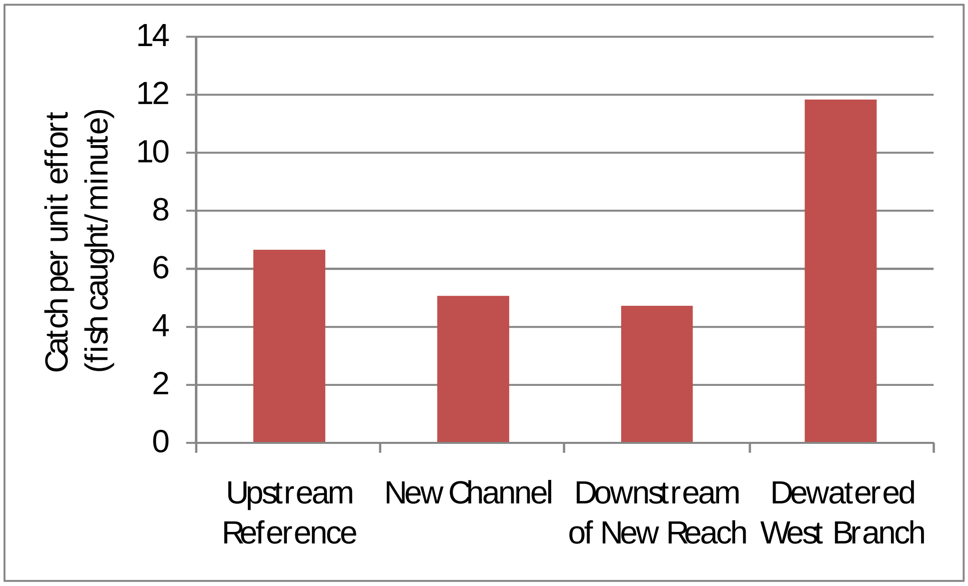


**Figure 6. Fish abundance in the Suncook River fifteen months after the avulsion**

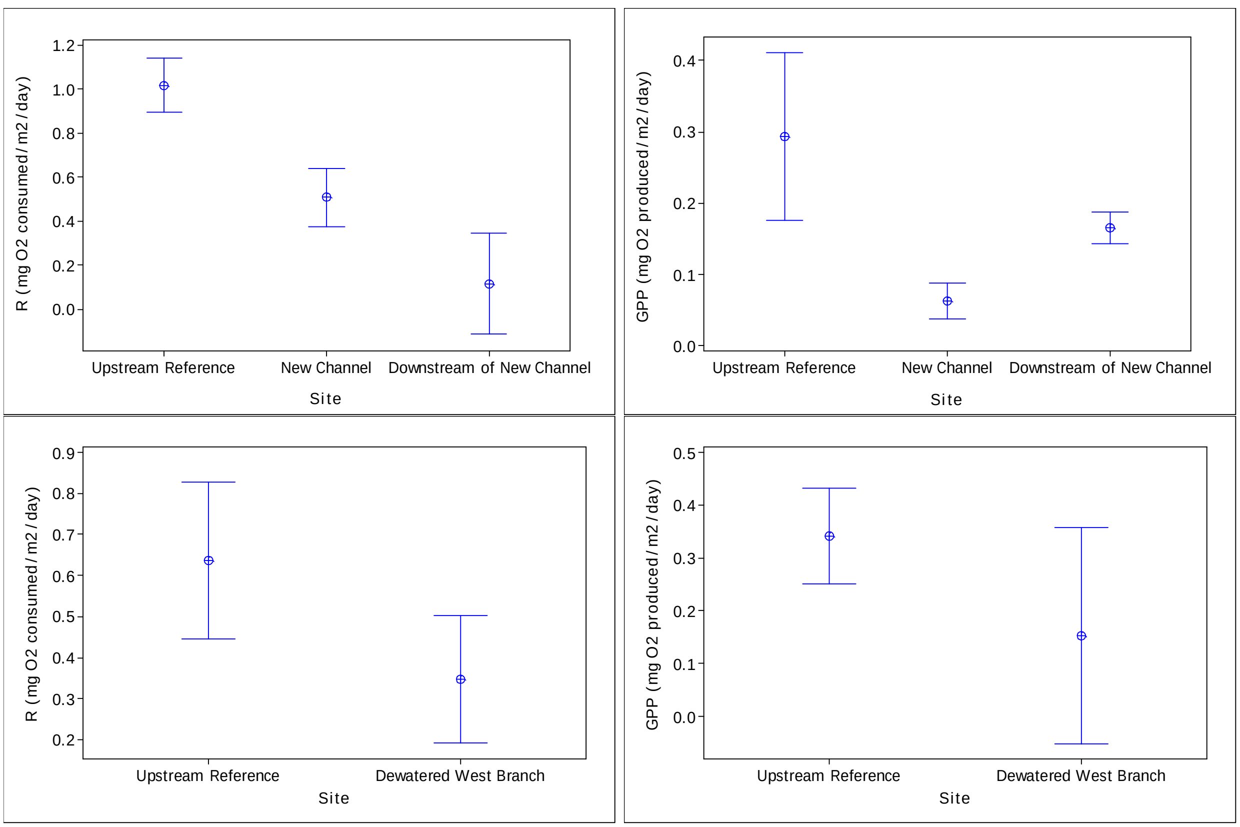


**Figure 7. (a) Community respiration in the east branch of the Suncook River; (b) gross primary production in the east branch of the Suncook River; (c) Community respiration in the west branch of the Suncook River; and (d) gross primary production in the west branch of the Suncook River**

*Preliminary Conclusions*

The May, 2006 avulsion has led to long-lasting changes in the Suncook River. In the eastern branch, reduced substrate size and stability and increased concentrations of suspended solids have led to dramatic reductions in macroinvertebrate abundance and whole-stream metabolism, while effects on fish communities have been less severe. In the western branch, where dewatering has altered water chemistry and reduced instream habitat area, whole-stream metabolism and fish species evenness have declined, while fish abundance has increased. There is a need for further research into the independent and combined roles of substrate size, substrate stability, suspended sediment, water chemistry, and instream habitat area in influencing lotic communities and ecosystem function.

**Publications, presentations, awards**

Traister, E.M. and W. McDowell. Physical, biological, and biogeochemical response of a northeastern river to a severe flood. (poster) Presented at the AGU 2006 Fall Meeting in San Francisco, CA.

Traister, E.M. and W. McDowell. Physical, biological, and biogeochemical response of a northeastern river to a severe flood. (poster) Presented at the UNH 2007 Graduate Student Research Conference in Durham, NH. (received poster award)

Traister, E.M. and W. McDowell. Physical, biological, and biogeochemical response of a northeastern river to a severe flood. (poster) Presented at the ESA 2007 Annual Meeting in San Jose, CA.

Daley, M.L., Traister, E.M. and W.H. McDowell. 2008. Physical, Biological, and Biogeochemical Response of the Suncook River to the May, 2006 Avulsion. Town of Epsom NH Public Meeting. March 2008.

**Publications from WRRC supported work completed in previous years and not reported previously (if applicable)**

Not applicable.

**Outreach or Information Transferred**

Water chemistry data was shared with the New Hampshire Department of Environmental Services.

A presentation was given to two fourth grade classes at Epsom Central School on 5/4/07 about the Suncook River avulsion.

**Number of students supported (and degree level, undergrad, Master, PhD)**

Equipment, sample analysis, and travel were provided for one PhD student, and support was provided for two laboratory technicians. Three undergraduate students were also supported for assisting with field and lab analyses.

References

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